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CASE HISTORY: ARRAYS FOR A 500 KHZ ELECTRONICALLY SCANNED SONAR

by

J. R. DUNN

of

UNIVERSITY OF BIRMINGHAM

1.0 System Requirements

The Birmingham sector-scanning sonar uses a carrier frequency in water of 500 kHz, the wavelength, λ_w, being therefore 3.0 mm. The receiving system has 32 channels and has an effective beamwidth in the scanned direction of 1°; in the orthogonal direction the beamwidth is about 15°. The transmitting array has to give a directional response which is as constant as possible over the 30° scanned sector, with a rapid fall to low sidelobes immediately outside this; the orthogonal beamwidth matches that of the receiver. The original specification called for a modest working depth, since it was expected that operations would be mostly carried out in shallow water and there was a suitable housing available which would be unsafe at depths greater than about 15 m.

2.0 The Individual Elements

2.1 The Receiving Array

The specification of a 30° sector requires the elements to be spaced at intervals (centre to centre) of $2\lambda_w$; since they should be closely packed, this should also be the width of each one. It is explained in the companion paper (1) that $2\lambda_w$ is an undesirable width for a single element, leading to inefficient radiation, and so each channel has a pair of elements, each a little under $0.9\lambda_w$ wide, the gap of $0.1\ \lambda_w$ being required for a spacer. For 500 kHz the resonant thickness of a large plate of PZT-4 would be 4.0 mm., but in this case the actual thickness is 2.9 mm., this clearly demonstrates the dependence of the resonance on the width (2.7 mm.). The length of the bars for the 15^o vertical beamwidth is $4\pi_w$, 12.0 mm., and this presents no problems.

2.2 The Transmitting Array

The "square topped" directional pattern is designed by the superposition of deflected sin x/x patterns (2), and this leads to an amplitude taper which follows a sin x/x curve. It was calculated that a row of 19 elements at intervals of $0.75\lambda_w$ would give a suitable pattern; the relative amplitudes are such that the central three elements correspond to the main lobe of a sin x/x pattern and carry most of the power, and approximately half of the remaining elements are driven in anti-phase. The element width is $0.66\lambda_w$, again allowing for spacers, and this is narrow enough for there to be no problems in getting proper radiation. The thickness was chosen as 3.0 mm., slightly thicker than for the receiving elements in the expectation that the resonant frequencies would be the same.

2.3 Selection of the Elements

The elements for the receiving array were matched on the basis of the free resonance in air, with a small bias towards matching the free capacitances in pairs. Thos for the transmitting array were matched principally on the capacitance. In both cases they were arranged in the respective arrays in the order of their resonances.

3.0 Assembly of the arrays

3.1 General arrangement

This is shown in the figure, which is an end view of the cross-section through both arrays as they are arranged close together on the lid of the housing. The elements are located on narrow shoulders in the insulted supports; this ensures that they all lie in the same plane. The support is slotted for the wires from the front and back of each element to pass to the feed-throughs. The slots, machined at accurate intervals, were used as guides in locating the elements along the length of each array. The elements are separated by polythene sheet, 0.25 mm. thick, which ensured that they were not in contact before potting and which should reduce the direct acoustic coupling between them to some extent.

3.2 Backing material

The space behind the elements is filled with an epoxy resin - PFA spheres composite mixture 10 mm. thick. The ratio of PFA to epoxy is about $1\frac{1}{2}$: 1 by weight, which makes a relatively dry misture, but this is easier to put into position without voids than a wetter one. From recent work by Pemore (3) the attenuation is probably too low, but there is no evidence in the performance that reflections from the back of the housing cause any difficulties; the insulting block probably helps having an impedance which is not too different. The assembly was carried out by filling the cavity with the backing mixture and then putting the elements in place before the epoxy cured; in this way it was possible to ensure that they were fully in contact with the backing and that they were properly located in line.

3.3 Facing material

This is a casting epoxy resin, the same as in the backing mixture, which was pured into place under vacuum in order to eliminate air bubbles. This is not completely reliable, perhaps because air is absorbed to the surfaces and is then disturbed by the epoxy, or the bubbles may be of improperly mixed hardener vapourised under vacuum. There is an advantage in putting on a thicker layer than is really necessary and then machining off the surface with the imperfections. In any case the thickness over the elements is to a small extent critical for the best results, a quarter-wave layer or thereabouts being optimum. The usual technique for curing is to leave the array at room temperature for about 24 hours and then to give it a post-cure at about 50 to 60°C for three hours; it is unwise to exceed this temperature, since the epoxy would be cured thermally expanded and it may then crack away from the housing when it cools down to room temperature.

4.0 Results

The usual measurements of admittance were made on the individual elements in the transmitting array and on pairs in the receiving one. The results are summarised in the following table of means and standard deviations.

	Transmitter		Receiver	
	mean	s.d	mean	s.d
Max. conductance mA.	0.372	0.015	1.34	0.14
Resonant frequency kHz	504.2	5.3	492.4	5.6
Q in water	9.60	0.90	7.52	0.88
Clamped capacitance pF.	80	2	210	10
Relative sensitiviey				9%

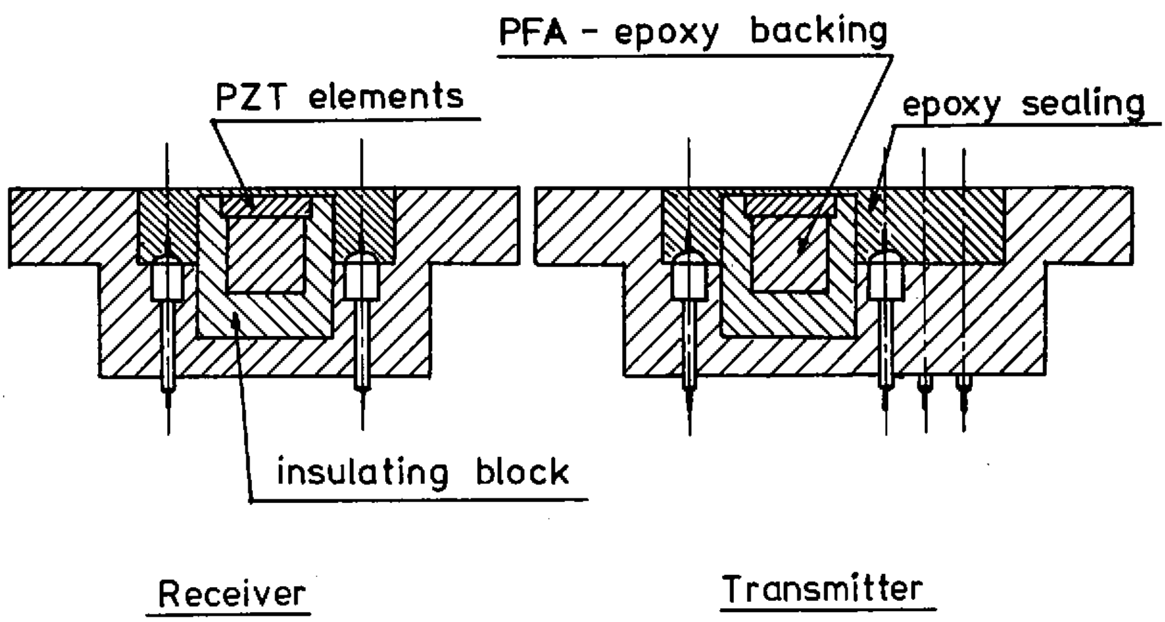
The receiving sensitivity included the pre-amplifiers, which could have a 10% scatter in gain due to tolerances in components; no mean value is given, since only comparative measurements were made. These results were quite acceptable, and the expected performance of the sonar was achieved, although the mean frequencies of the two arrays were more different than expected (the operating frequency is 500 kHz). The average efficiency is about 40%, due mainly to the backing having an undesirably high acoustic impedance; this is not a great disadvantage for the transmitter, since the small effective size of the array, taking into account the amplitude taper, limits the useful power into the water to about 10 W and a 25 W. power amplifier is no larger than a 10 W. one. On the other hand there is a loss in signal/noise performance in the receiver of 4 dB., i.e. 10 log (efficiency), but this in fact reduces the maximum range only by 5 m. in 70 m.

The directional patterns were generally as predicted, except that the vertical beamwidth was about 12° rather than the expected 15°, and this may be due to some radiation from the epoxy facing beyond the ends of the elements. The individual sensitivities of the elements were compensated by adjusting the individual drives on the transmitting array and by setting the gains of the pre-amplifiers on the receiving system, the former from calculations of sensitivity from conductance at resonance and the latter from the direct measurement using an active source in the water.

5.0 References

1. J. R. Dunn, A review of problems in high-frequency transducers. These Proceedings, paper no.
2. D. G. Tucker, J. R. Carey, The design of arrays to have constant response over a specified beamwidth with specified rates of cut-off at the edges of the beam. University of Birmingham, Dept. of Electronic and Electrical Engineering, memorandum no. 396, August 1969

3. J. M. Pelmore, Ultrasonic properties of materials for transducer use. These Proceedings, paper no. 6·0



500 KHz Scanner Arrays: cross section